Graph Deep Learning in Species Distribution Modelling

A Spatial Simulation

Reinout Vandenabeele

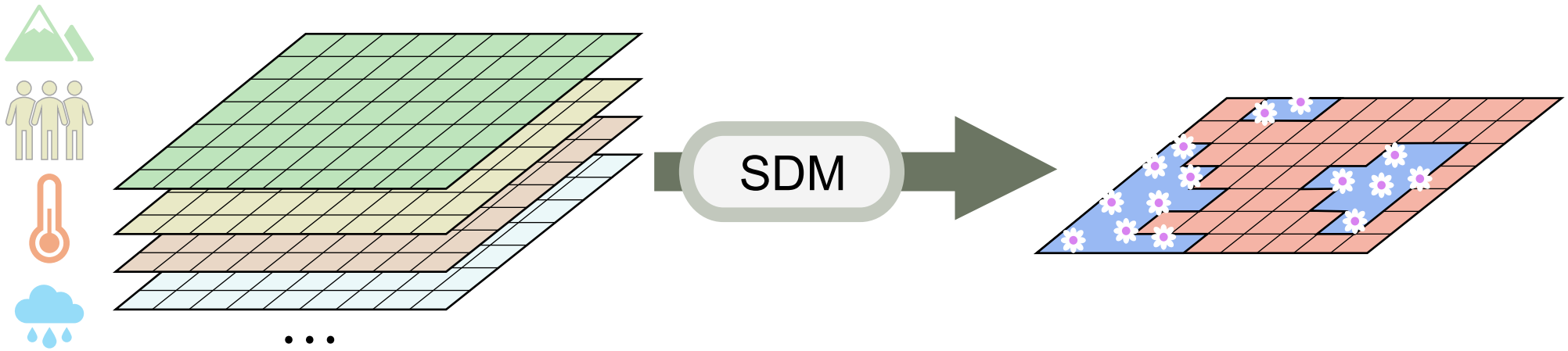
Project 1166125N

DEPARTMENT OF **EARTH AND ENVIRONMENTAL SCIENCES**
KU Leuven - BELGIUM

✉reinout.vandenabeele@kuleuven.be

Species distribution models (SDMs)

Biodiversity | Conservation | Climate change | Invasive species | Ecosystem disturbance | . . .



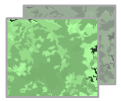
Species distribution models (SDMs)

- State-of-the-art SDMs: deep learning-based

Advantages

Joint modelling

Complex predictor interactions



Spatial context

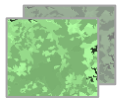
Species distribution models (SDMs)

- State-of-the-art SDMs: deep learning-based

Advantages

Joint modelling

Complex predictor interactions



Spatial context

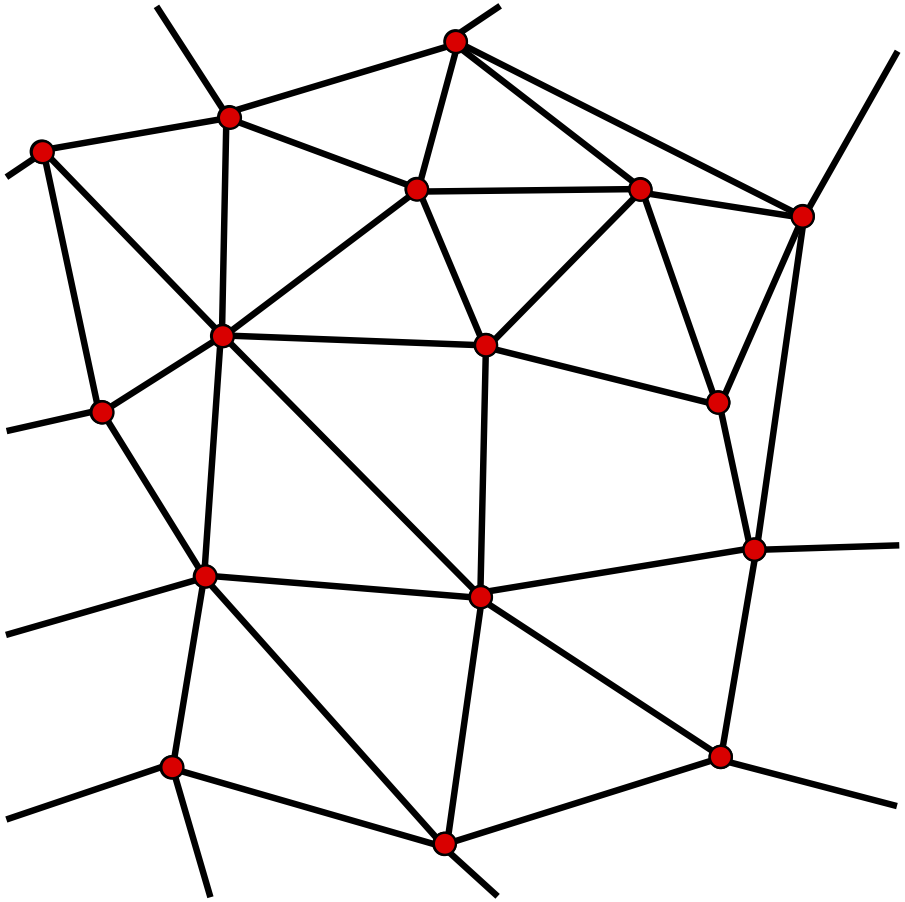
Limitations

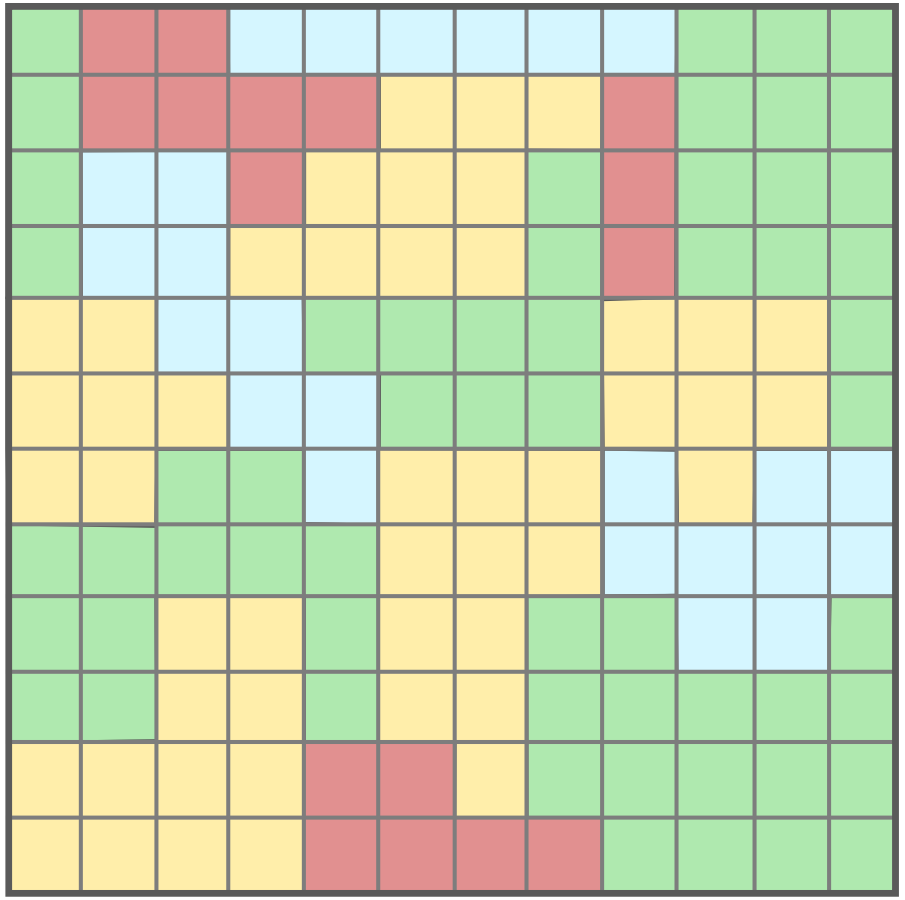
Pixel-based

Limited topological info

Limited species relationships

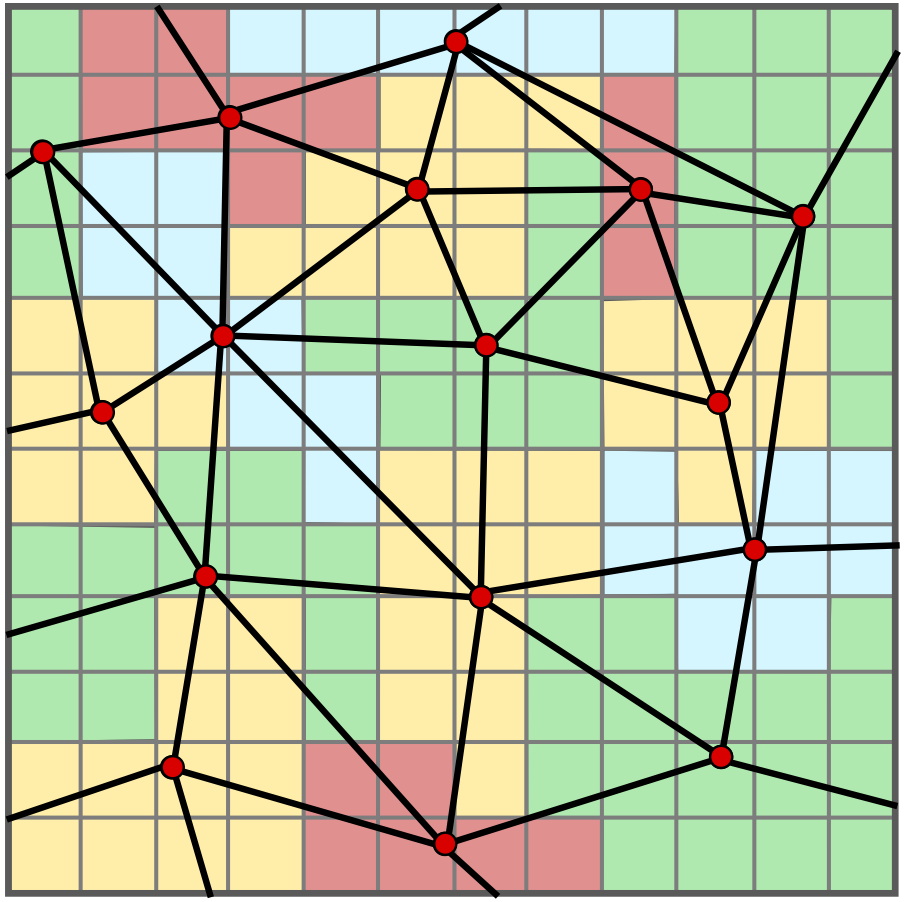
Spatial graphs





Pixels → nodes

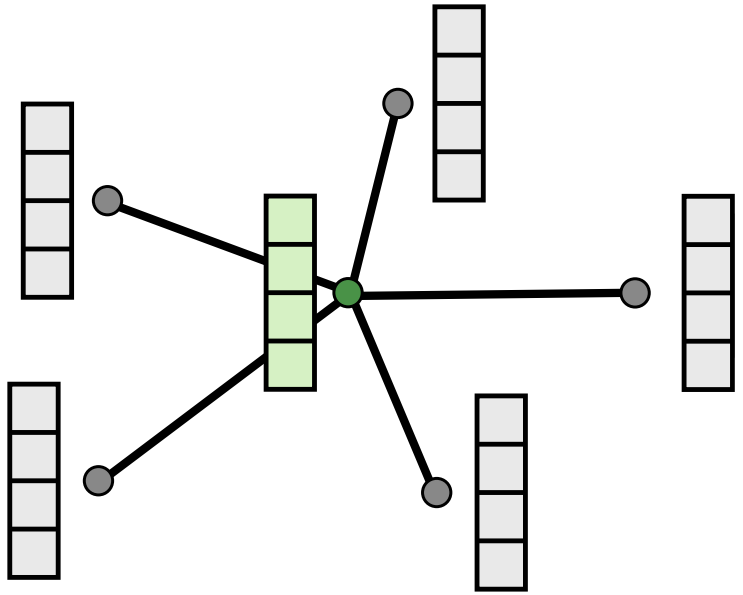
Spatial graphs



Pixels → nodes

Graph deep learning

- Graph convolutions passing neighbour information
  - Message calculation, passing & aggregation
  - Update step



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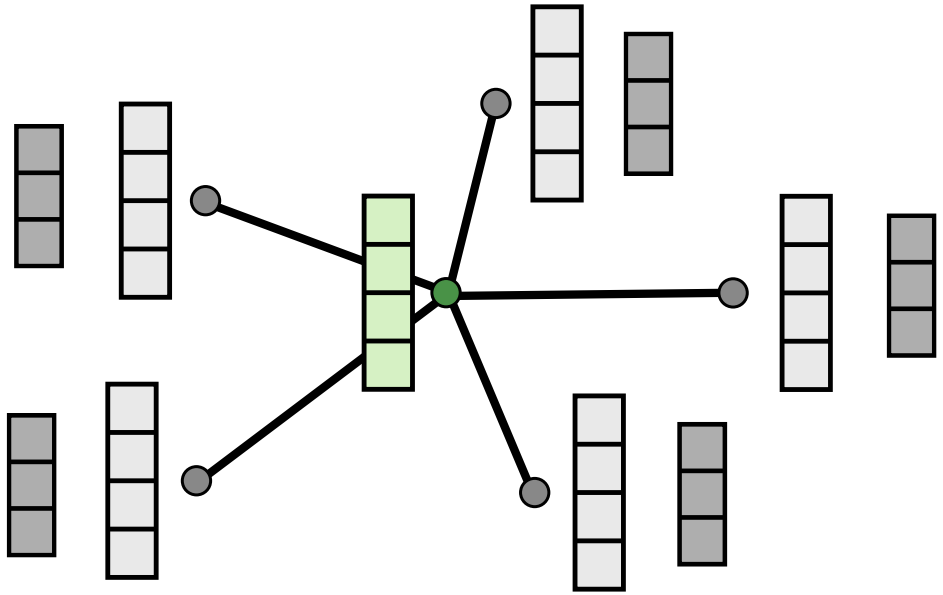

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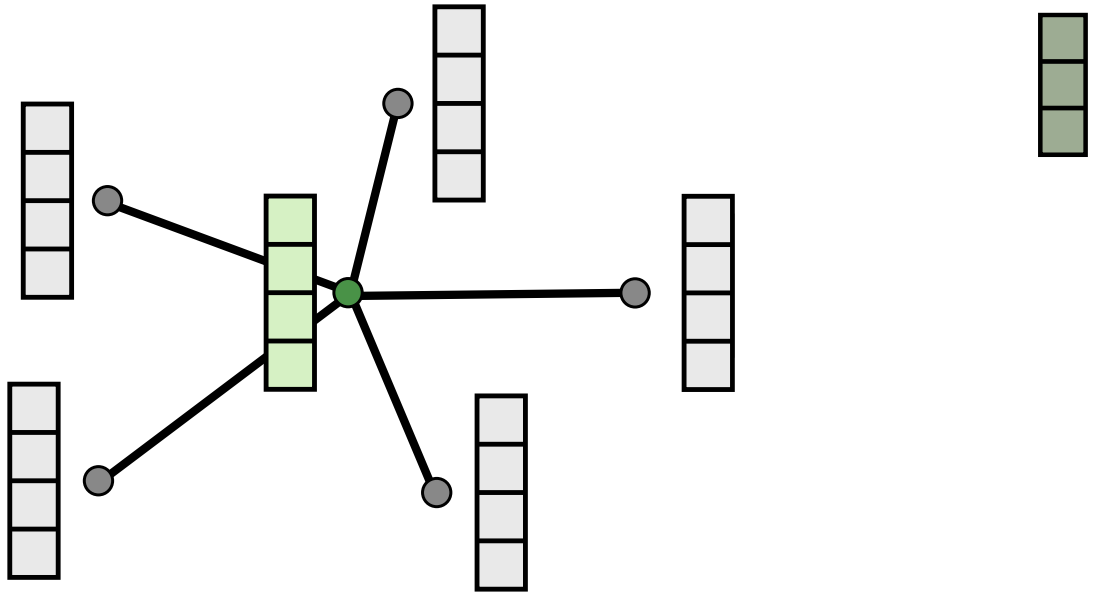

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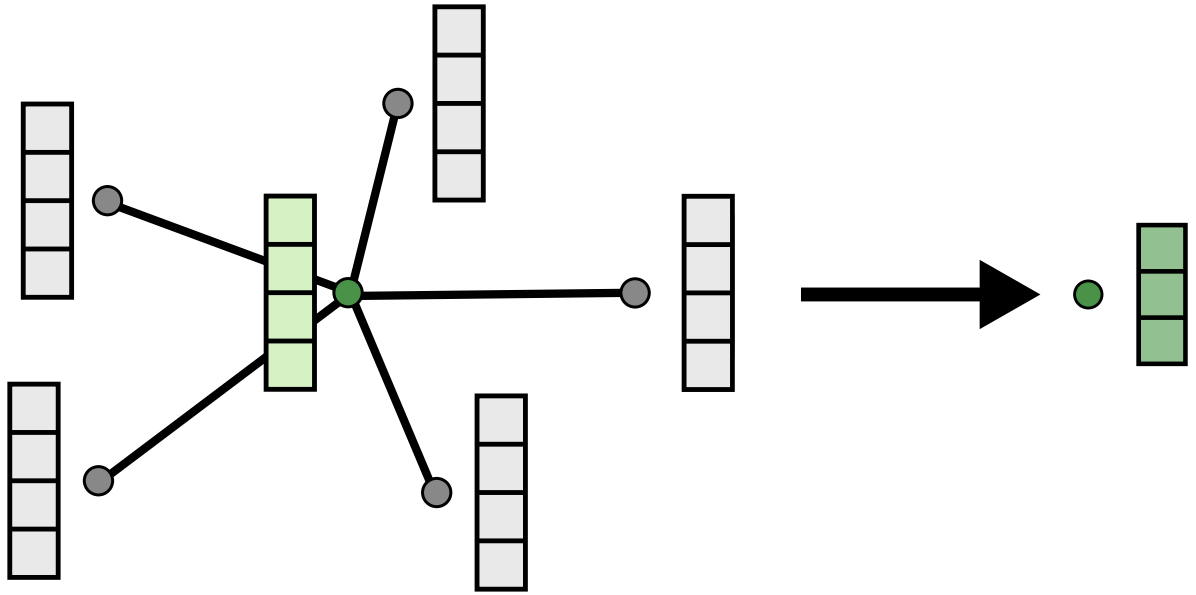


Graph deep learning

- Large potential

Current Limitations

Pixel-based

Limited topological info

Limited species relationships

Opportunities
Graph deep learning

Irregular formats 

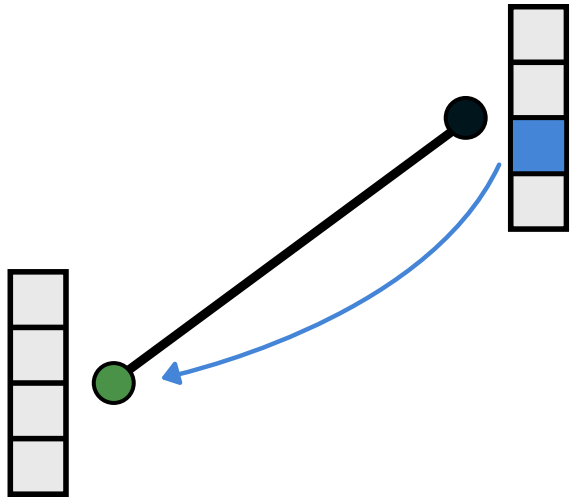
Topological information 

Species relationships 

Wu et al., 2025 *Glob. Ecol. Biogeogr.*
Harrell et al., 2025 *ICLR*

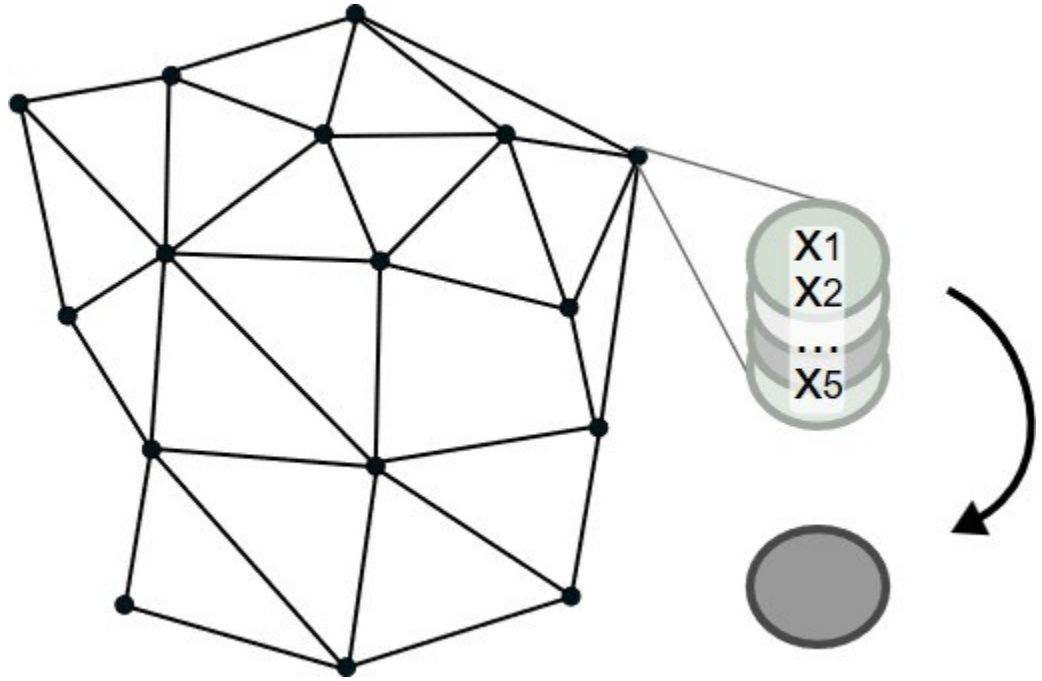
Simulations

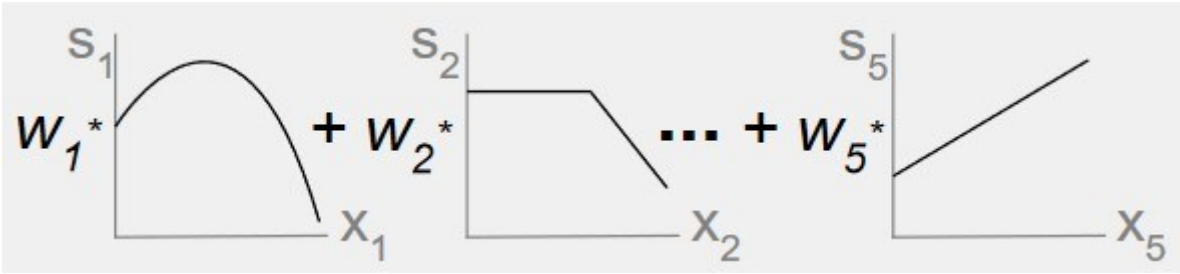
- Simulation of species presences/absences
  - Including adjacency effect
  - Ecologically motivated
- Comparison of predictive performance
- Evaluation of GNN performance



Simulations

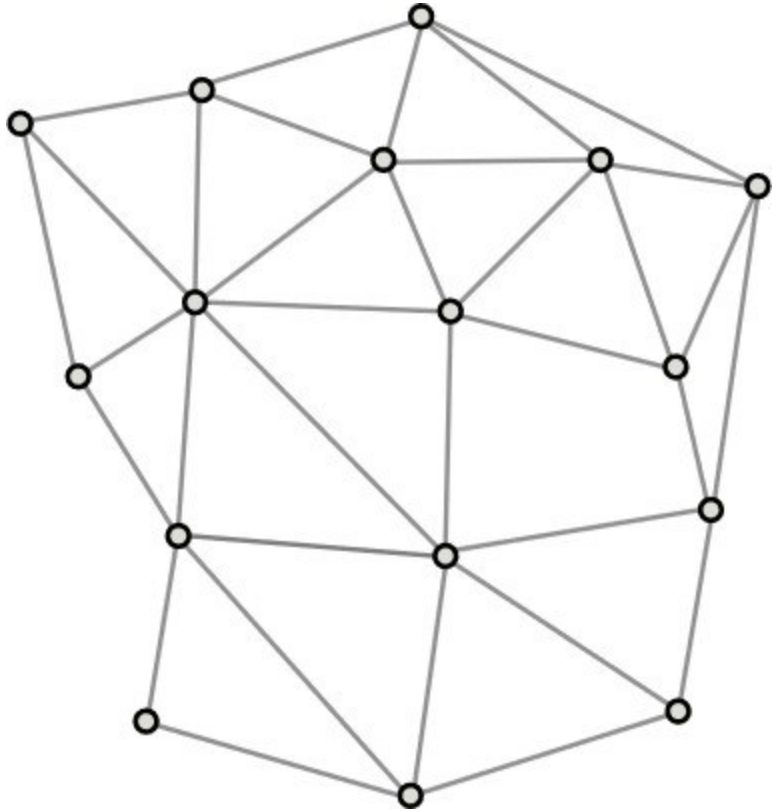
- Initial suitability = weighted sum of partial responses





Simulations

- Adjacency effect – weighted



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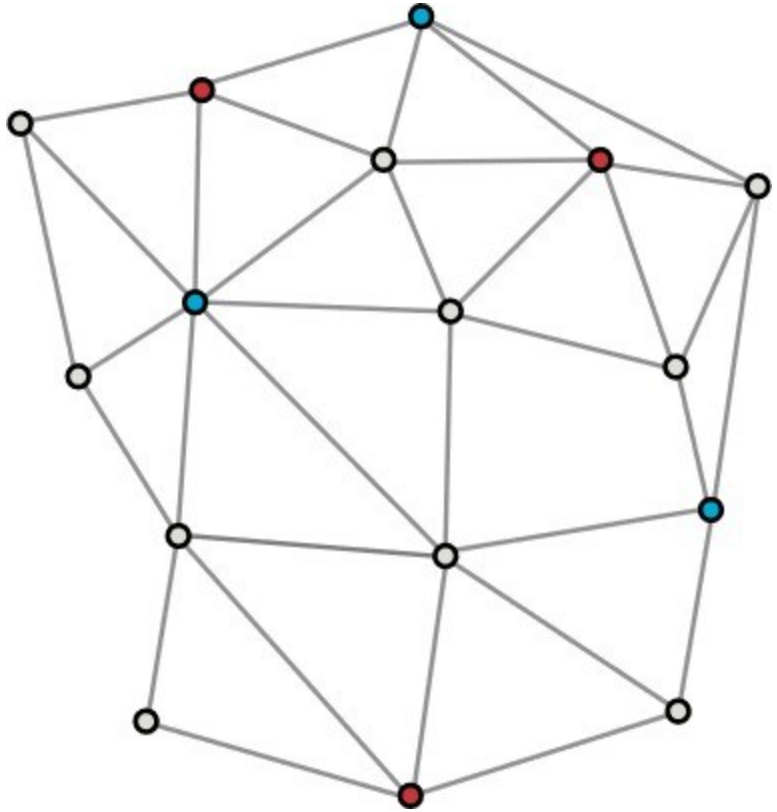

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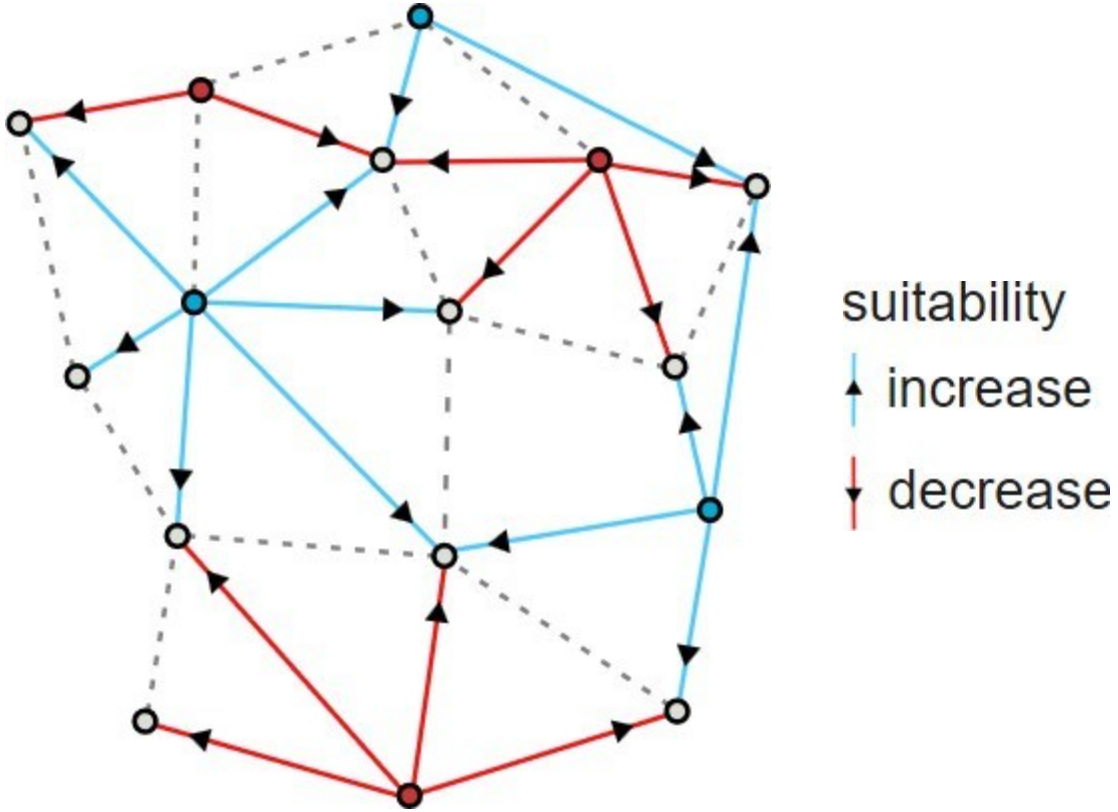

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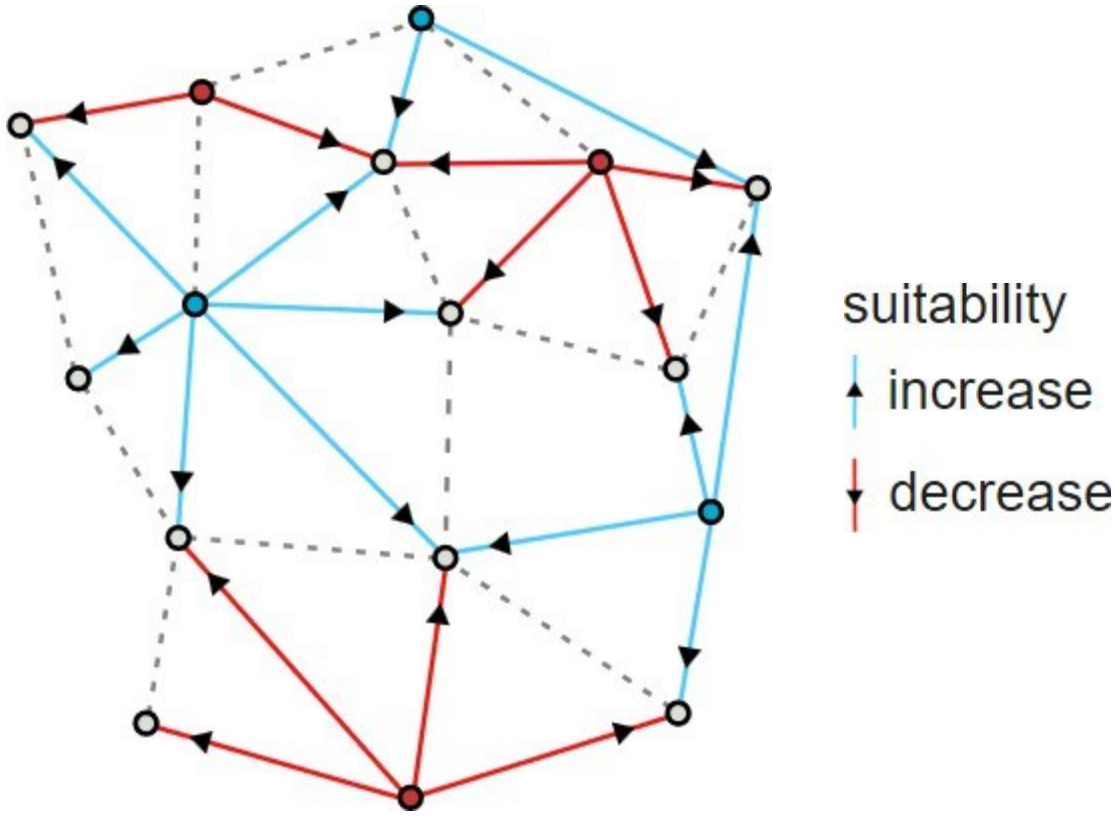
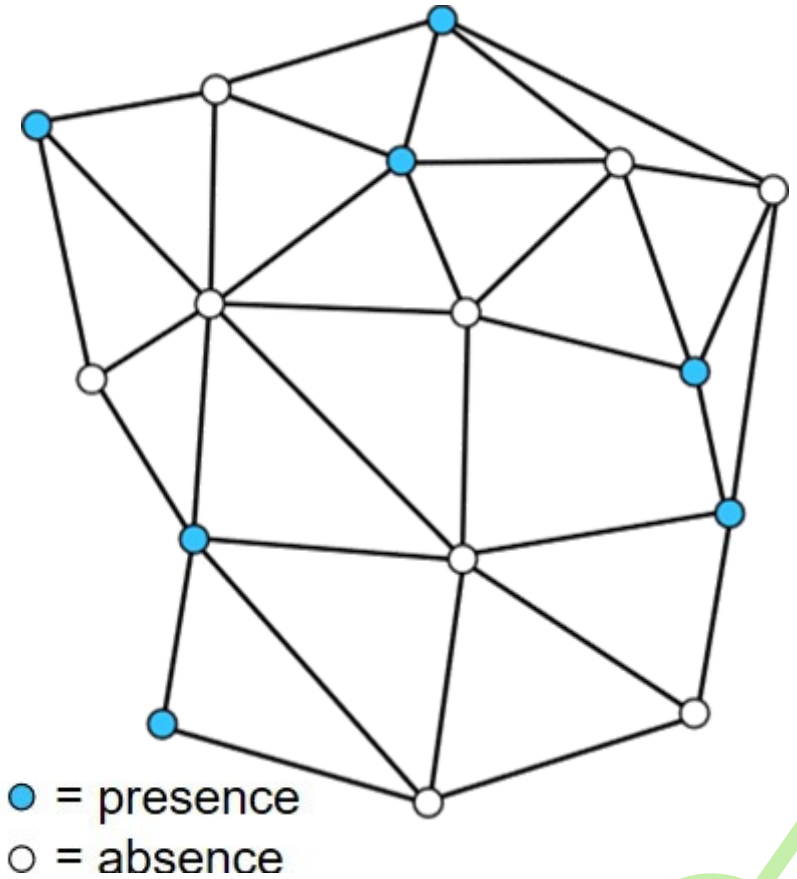
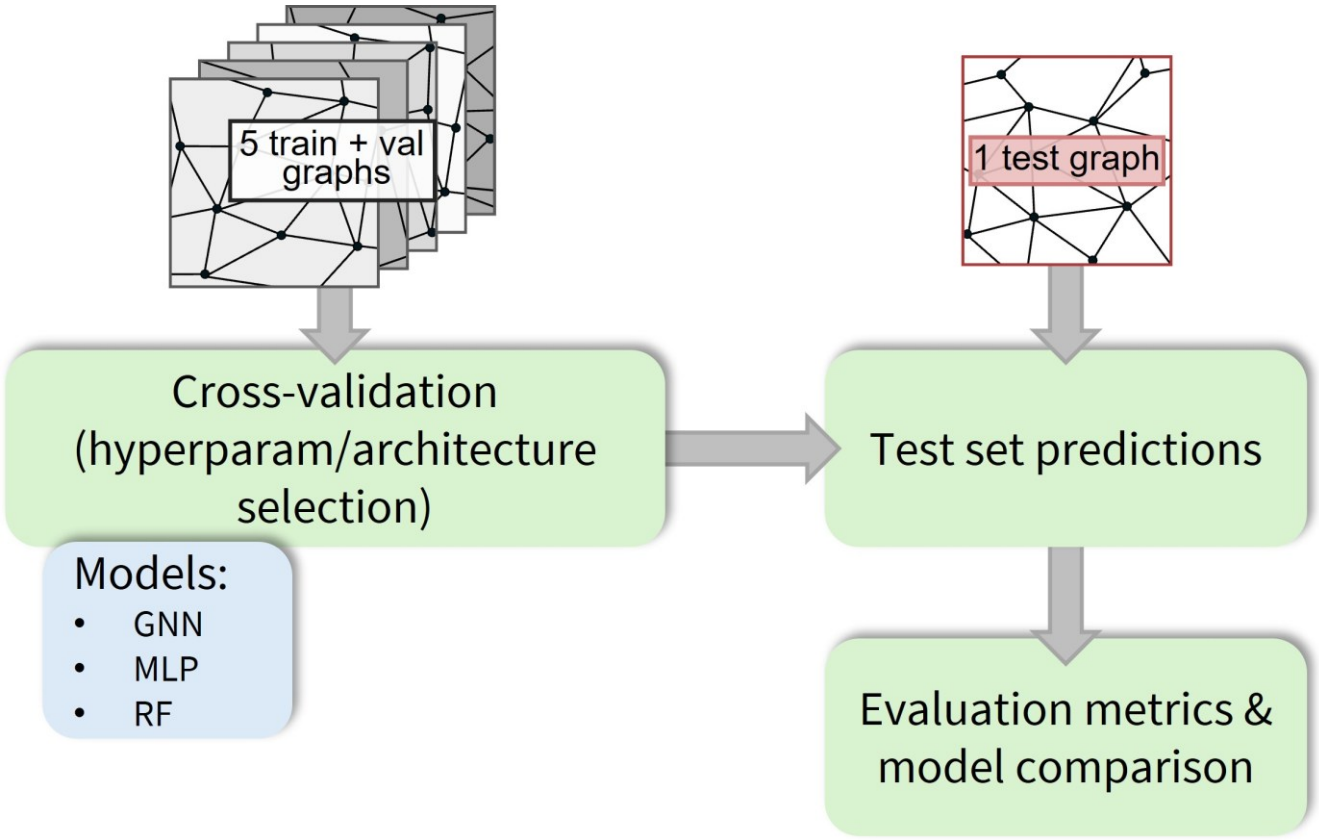


Labels:



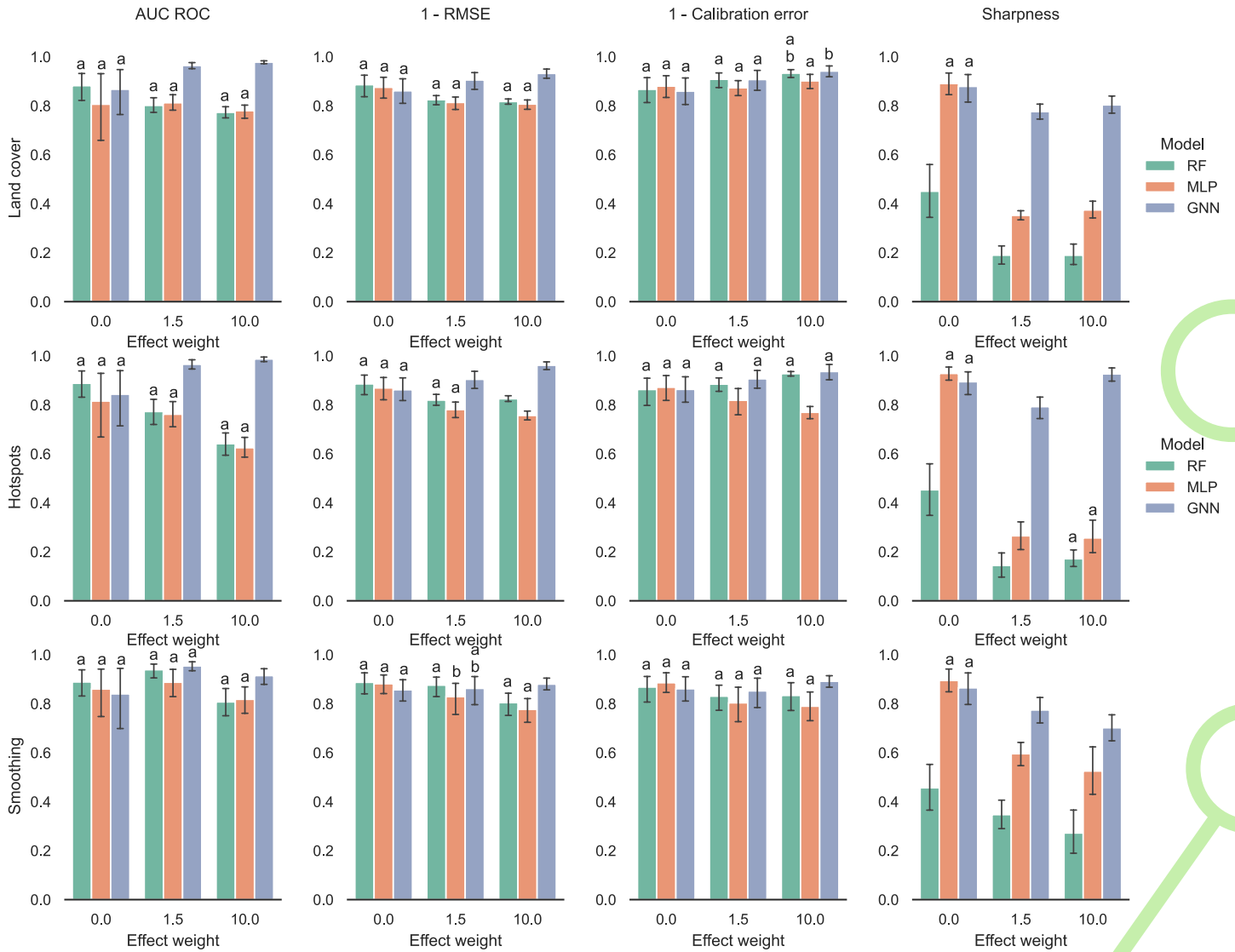
Simulations



x 3 (effects) x 3 (effect weights) x 15 (runs/species)

Results

- Similar performance for no adjacency effect
- MLP/RF: lack edge info
- Similar results for other adjacency effects

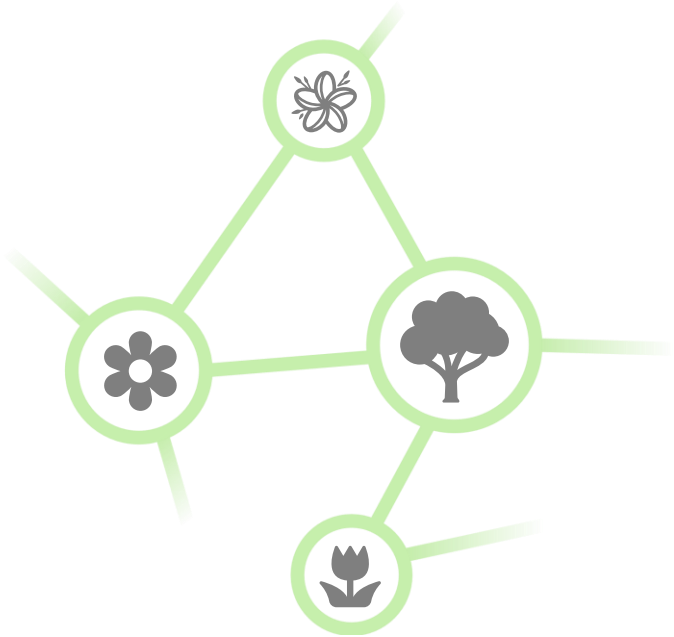


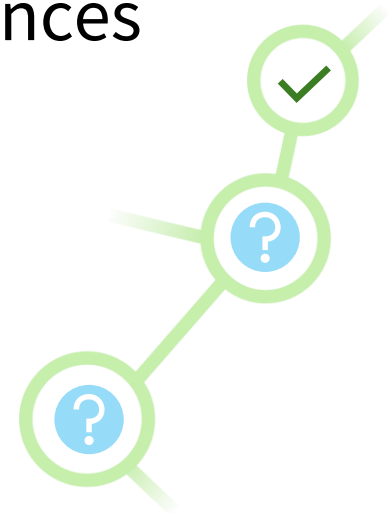
Generalized linear mixed models & pairwise post hoc tests
Significance at α=0.05

Further potential of graph deep learning

- Dispersal & occupancy: leveraging known presences

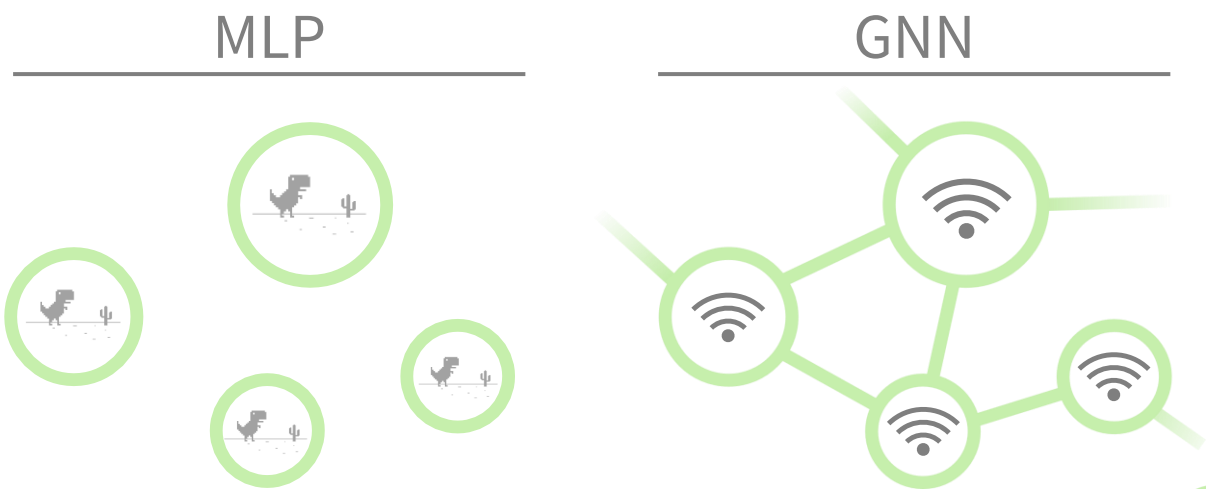
- Species networks
  - Co-occurrence
  - Phylogeny
  - Trait information

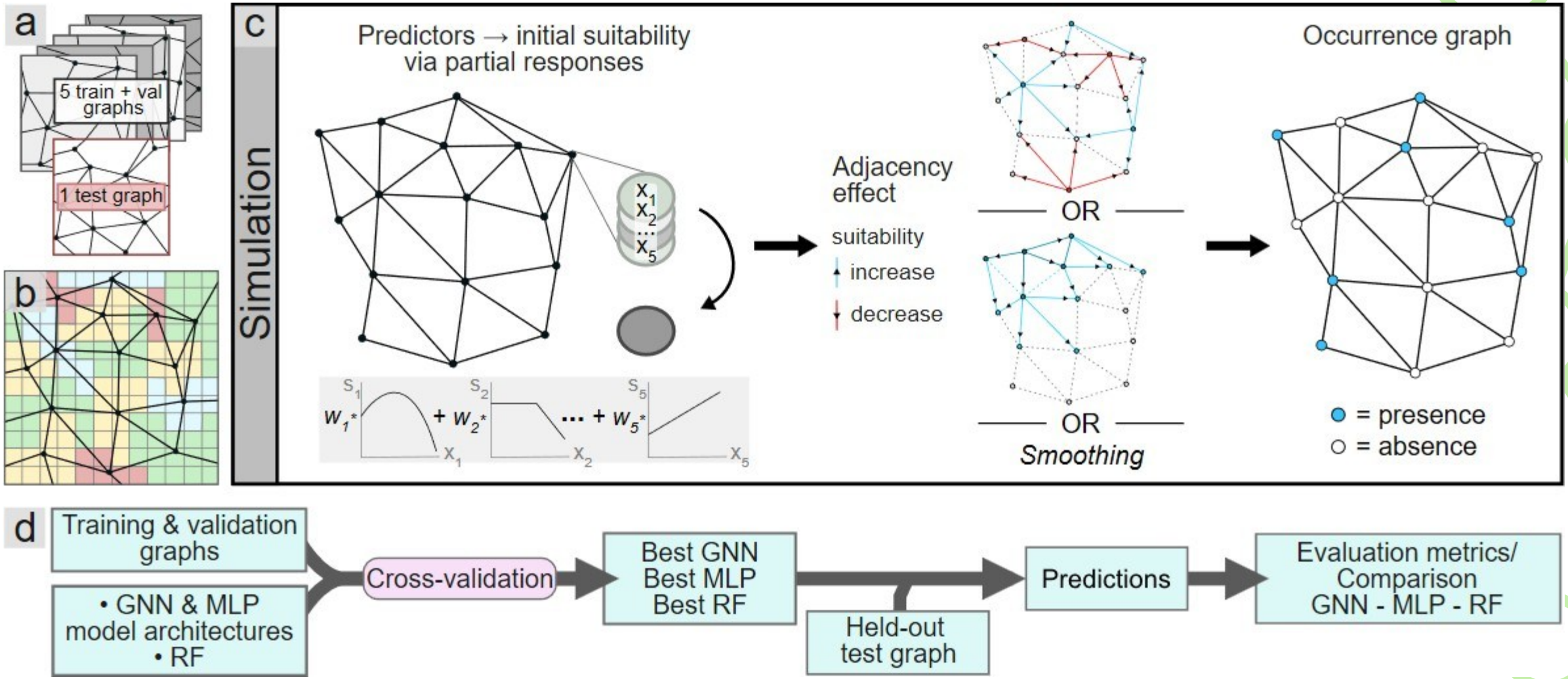




Take home messages

- We consider species distributions in a landscape graph instead of grid
- If species distributions depend on an adjacency effect, GNNs perform better → can leverage edge information
- Further potential for occupancy & species networks





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